

SAMPLES FROM MARTIAN CRATERS: ORIGIN OF THE MARTIAN SOIL BY HYDROTHERMAL ALTERATION OF IMPACT MELT DEPOSITS AND ATMOSPHERIC INTERACTIONS WITH EJECTA DURING CRATER FORMATION.

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The origin of the martian soil is an important question for understanding weathering processes on the martian surface, and also for understanding the global geochemistry of Mars. Chemical analyses of the soil will provide a unique opportunity to examine what may be a crustal average, as studies of loess on the Earth have demonstrated [1]. In this regard the origin of the martian soil is also important for understanding the chemical fractionations that have affected the composition of the soil. Several processes have been suggested that are likely to contribute to the martian soil. Processes connected with volcanism include palagonitization of basaltic melts [2], and alteration of volcanic glass under ambient conditions [3]. Processes connected with impacts include alteration of impact-produced glass under ambient conditions [3], alteration of hot ejecta during the actual ejection of the material from the crater [4] and hydrothermal alteration of impact deposits [5,6]. Recent investigations of terrestrial craters and experimental studies have provided strong support for the role of impact related processes in martian soil formation. Investigations of terrestrial craters have shown that hydrothermal alteration is commonly found in impact crater deposits [7]. Studies at the Ries crater in West Germany have shown that clays formed by hydrothermal alteration are very abundant in suevite deposits, where clay contents of 15 wt% are found [6,8]. The mineralogy of the clay, which is montmorillonite with no interstratified illite, indicates a low temperature origin for the clays, suggesting that most of the hydrothermal alteration takes place after the impact deposits have cooled below the boiling point of water [6]. This stage of the cooling history of an impact deposit will also be the longest in duration due to low thermal gradients and the absence of heat transport due to boiling and loss of steam.

Experimental alteration studies of highly shocked minerals have shown that dissolution of the minerals is greatly enhanced, even when the increase in surface area is accounted for [9]. This process may enhance the production of clays by hydrothermal alteration of shocked minerals. The alteration of shocked minerals under ambient conditions may also be possible, in contrast to the conclusion of Gooding [10] who considered the thermodynamic stability of unshocked silicate minerals on the martian surface.

Evidence, however, for the rapid alteration of material during the process of ejection from a crater [4] has not emerged. Experimental studies do not indicate evidence for this mechanism [11], and the low temperature nature of the clays found at the Ries does not lend support to this idea [6].

Many questions remain about the importance of hydrothermal alteration of impact deposits on Mars. This mechanism is apparently most effective on suevite deposits, but it has been argued that the amount of impact melt generated at craters where suevite is found, especially at the Ries, is much less than in craters with coherent melt sheets [4]. However, if a significant fraction of the clay matrix in the suevite at the Ries was originally impact glass then the volume of impact melt in the deposits may be similar to craters with coherent melt sheets [8]. In addition, the central

10 square kilometers of the Ries basin has not been explored by drill holes, leaving the possibility that a coherent melt sheet could be present. The question of whether suevite deposits are common on Mars is also unknown. Another conclusion of Kieffer and Simonds [4] is that suevite deposits are formed by impact into water-bearing sedimentary rocks, which might be common on Mars. At the Ries, however, which formed in a target with 500 m of sedimentary cover, the clasts in the suevite consist almost entirely of the underlying crystalline basement [8]. The formation of suevite may still be connected with the presence of water-bearing materials, but the actual mechanism may be connected with atmospheric interactions instead of processes within the crater.

The importance of atmospheric effects during large impacts has been emphasized by the studies of the K/T boundary event on the Earth. Unfortunately, only limited evidence remains at terrestrial craters because of erosion. At the Ries, such evidence includes the indication that outside of the crater the suevite was not deposited from a rapidly flowing base surge, since the contact of the suevite with the underlying ejecta deposits is undisturbed [6]. This may indicate interaction of the ejecta with the atmosphere that could involve a late-time circulatory motion of the decelerated ejecta cloud [12]. Within the crater the presence of a layer 20 to 60 m thick containing accretionary lapilli at the top of the suevite suggests the possible existence of a fireball type of cloud over the crater itself [13]. Determining the presence or absence of suevite deposits in martian impact craters and obtaining evidence of atmospheric effects during formation of martian craters will help address the nature of crater formation on planets with atmospheres.

Sampling strategy: Investigation and sampling of a large martian crater will represent the first detailed study of an impact crater on another planet. Questions regarding hydrothermal alteration of impact produced materials could be explored with samples from martian craters. Since Mars is inferred to have had a denser atmosphere in the past, when water was more available, samples from a relatively old crater may be most desirable. Ideally samples from within the ejecta blanket external to the crater should be sampled as well as the impact deposits within the crater itself. A core sample within the crater could sample both the fall-back deposits that record evidence of atmospheric interactions, and impact melt deposits, although drilling to tens of meters depth might be required. An old eroded crater may provide surface exposures of these deposits. Samples from younger craters should also be sought because they are more likely to preserve evidence of atmospheric interactions. For studying global geochemistry from soils, samples of widely differing ages should be sought.

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